SCINTILLATORS FOR THE PHYSICAL SCIENCES

Nuclear Enterprises

THORN EMI

INDEX

Also available: Brochure No 126C Crystal Scintillators and Radiation Detectors, Brochure No 126L Scintillators for the Life Sciences.

TABLE OF PHYSICAL CONSTANTS OF SCINTILLATORS

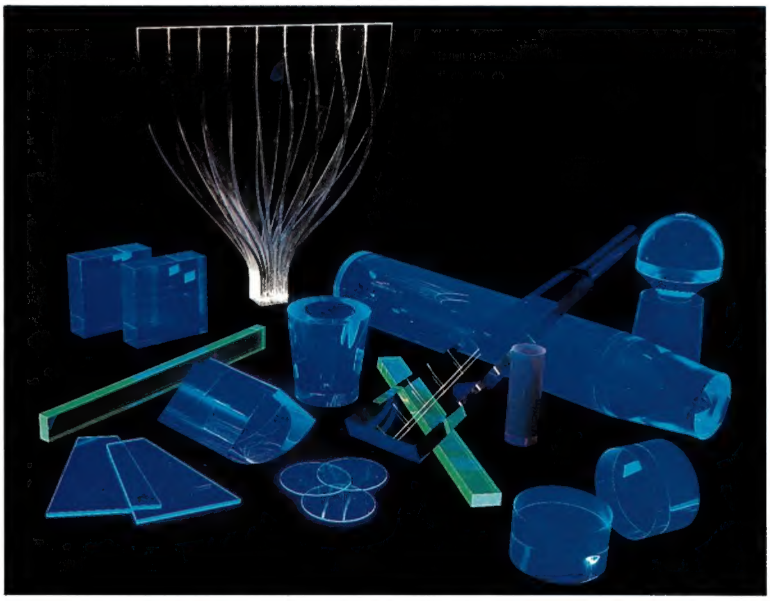
	Scintillator	Page Ref.	Type	Density	Refractive Index	Melting Softening or Boiling Point °C	Light Output (% Anthracene)	Decay Constant, Main Component ns	Wavelength of Maximum Emission nm	Content of Loading Element (% by wt.)	H/C No. of H Atoms/ No. of C Atoms	Principal Applications
PLASTIC	NE 102A	5-11	Plastic	1·032	1·581	75°	65	2·4	423	....	1·104	γ, α, β, fast n
	NE 104	5-11	Plastic	1·032	1·581	75°	68	1·9	406	....	1·100	ultra-fast counting
	NE 104B	5-11	Plastic	1·032	1·58	75°	59	3·0	406	....	1·107	with BBQ light guides
	NE 105	6	Plastic	1·037	1·58	75°	46	....	423	....	1·098	dosimetry
	NE 110	5-11	Plastic	1·032	1·58	75°	60	3·3	434	....	1·104	γ, α, β, fast n, etc.
	NE 111A	5	Plastic	1·032	1·58	75°	55	1·6	370	....	1·103	ultra-fast timing
	NE 114	6-11	Plastic	1·032	1·58	75°	50	4·0	434	....	1·109	as for NE 110
	NE 160	6	Plastic	1·032	1·58	80°*	59	2·3	423	....	1·105	use at high temperatures
	Pilot U	5-11	Plastic	1·032	1·58	75°	67	1·36	391	....	1·100	ultra fast timing
	Pilot 425	6	Plastic	1·19	1·49	100°	....	....	425	....	1·6	Cherenkov detector
LIQUID	NE 213	13	Liquid	0·874	1·508	141°	78	3·7	425	....	1·213	fast n (P.S.D.)
	NE 216	L	Liquid	0·885	1·523	141°	78	3·5	425	....	1·171	α, β (internal counting)
	NE 220	L	Liquid	1·036	1·442	104°	65	3·8	425	0·29%	1·669	Internal counting, dosimetry
	NE 221	L	Gel	1·08	1·442	104°	55	4	425	....	1·669	α, β (internal counting)
	NE 224	13	Liquid	0·877	1·505	169°	80	2·6	425	....	1·330	γ, fast n
	NE 226	14	Liquid	1·61	1·38	80°	20	3·3	430	....	0	γ, insensitive to n
	NE 228		Liquid	0·71	1·403	99°	45	....	385	....	2·11	n
	NE 230	14	Deuterated liquid	0·945	1·50	81°	60	3·0	425	D 14·2%	0·984	(D/C) special applications
	NE 232	14	Deuterated liquid	0·89	1·43	81°	60	4	430	D 24·5%	1·96	(D/C) special applications
	NE 233	L	Liquid	0·874	1·506	117°	74	3·7	425	....	1·118	α, β (internal counting)
	NE235	14	Liquid	0·858	1·47	350°	40	4	420	....	2·0	large tanks
	NE 250	L	Liquid	1·035	1·452	104°	50	4	425	0·32%	1·760	internal counting, dosimetry
LOADED LIQUID	NE 311 & 311A	14	B loaded liquid	0·91	1·411	85°	65	3·8	425	B 5%	1·701	n, β
	NE 313	14	Gd loaded liquid	0·88	1·506	136°	62	4·0	425	Gd 0·5%	1·220	n
	NE 316	14	Sn loaded liquid	0·93	1·496	148·5°	35	4·0	425	Sn 10%	1·411	γ, X-rays
	NE 323	14	Gd loaded liquid	0·879	1·50	161°	60	3·8	425	Gd 0·5%	1·377	n
NEUTRON) (ZnS-type) and GLASS	NE 422 & 426	17	^{6}Li-ZnS(Ag)	2·36	....	110°	300	200	450	Li 5%	....	slow n
	NE 451	17	ZnS(Ag)-plastic	1·443	....	110°	300	200	450	....	....	fast n
	NE 901, 902, 903	18-20	Glass	2·64	1·58	c. 1200°	28	20 & 60	395	Li 2·3%	....	n, β
	NE 904, 905, 906	18-20	Glass	2·5	1·55	c. 1200°	25	20 & 58	395	Li 6·6%	....	n
	NE 907, 908	18-20	Glass	2·42	1·566	c. 1200°	20	18 & 62	399	Li 7·5%	....	n
	NE 912, 913	18-20	Glass	2·42	1·55	c. 1200°	25	18 & 55	397	Li 7·7%	....	n, β (low background)
CRYSTAL	Anthracene	C	Crystal	1·25	1·62	217°	100	30	447	....	0·715	γ, α, β, fast n
	Stilbene	C	Crystal	1·16	1·626	125°	50	4·5	410	....	0·858	fast n (P.S.D.), γ, etc.
	NaI(Tl)	C	Crystal	3·67	1·775	650°	230	230	413	....	....	γ, X-rays
	NaI(pure)		Crystal	3·67	1·775	651°	440†	60†	303†	....	....	γ, X-rays (fast counting)
	LiI(Eu)	C	Crystal	4·06	1·955	445°	75	1200	475	....	....	n
	CsI(Tl)	C	Crystal	4·51	1·788	620°	95	1100	580	....	....	heavy particles, γ (P.S.D.)
	CsI(Na)	C	Crystal	4·51	1·787	621°	150-190	650	420	....	....	heavy particles, γ (P.S.D.)
	CsI(pure)		Crystal	4·51	1·788	621°	500†	600†	c. 400†	....	....	heavy particles, γ (low energy)
	CaF_2(Eu)	C	Crystal	3·17	1·434	1418°	110	1000	435	....	....	β, X-rays etc.
	$CaWO_4$		Crystal	6·1	1·92	1535°	36	6000	430	....	....	γ (seldom used)
	ZnS(Ag)	16	Multi-crystal	4·09	2·356	1850°	300	70	450	....	....	α
	ZnO(Ga)		Multi-crystal	5·61	2·02	1975°	90	1·48	385	....	....	α

*Although NE 160 begins to soften very slightly at approximately 80° C, it retains its shape up to at least 150° C unlike other plastic scintillators such as NE 102A.

†At liquid nitrogen temperature.

Note: Under "Page Ref". L = Scintillators for Life Sciences Catalogue 126L.
C = Crystal Scintillators and Demountable Assemblies Catalogue 126C.

PLASTIC SCINTILLATORS

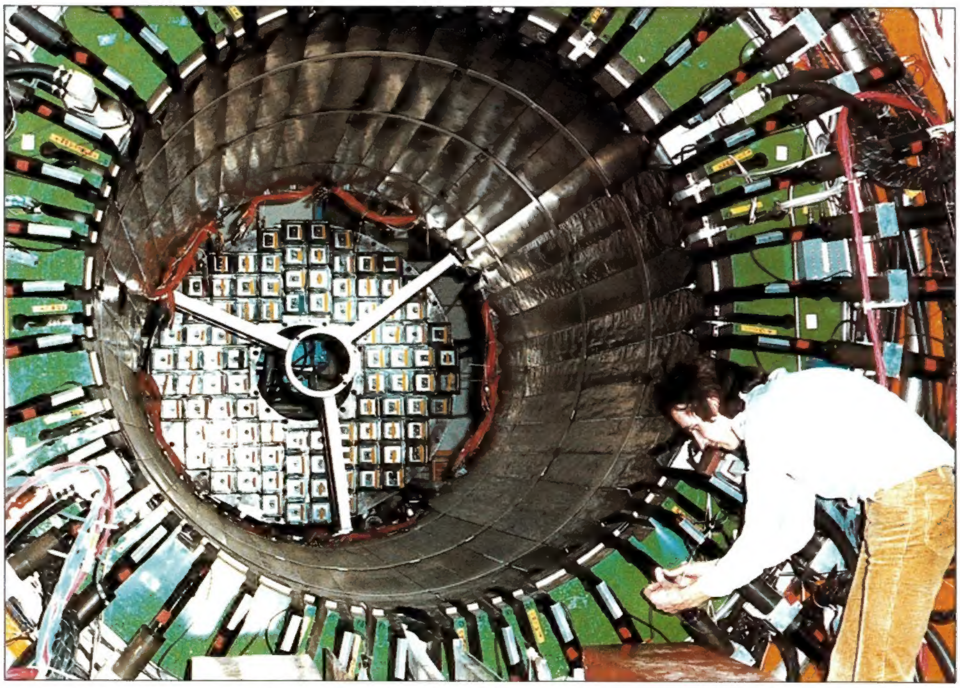


High performance, ease of handling, mechanical stability and relative low cost confer a versatility on plastic scintillators which makes them the ideal choice for large area and special form detectors. By meeting the increasing demand for larger area and faster detectors Nuclear Enterprises has maintained its role as the world's leading supplier of organic scintillators. Production capacity has been expanded and the capability now exists for fabricating sheets up to 3.5 metres long and cylinders of over 1 metre (40 inches) diameter. Nuclear Enterprises has over 25 years experience in this highly specialised field and welcomes the challenge of any special problems.

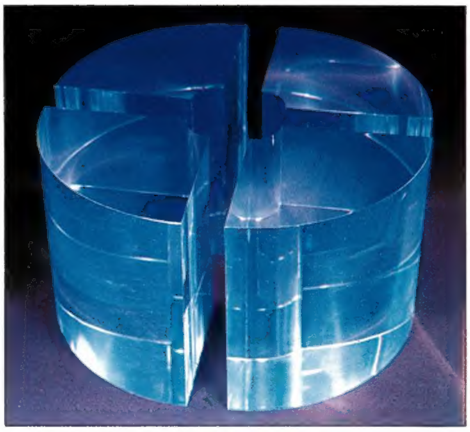
Major features of the Plastic Scintillator Range are:
NE 102A Plastic Scintillator, now accepted as a universal standard, NE 110 with unrivalled light transmission, NE 104B for use with BBQ light guides, and Pilot U with ultra fast decay time. Short descriptions of these outstanding detectors are given below. For full technical data see Table of Physical Constants (p. 3) and Technical Data on pp 9 to 11.

NE 102A Plastic Scintillator is first choice as a general purpose scintillator. An excellent balance of properties: high light output (65% anthracene), good light transmission (2.5m technical attenuation length), fast decay time (2.4 nanoseconds), have resulted in NE 102A's world wide recognition.

NE 110 Plastic Scintillator, with a technical attentuation length of over 4 metres for large blocks, is unrivalled for large area applications. NE 110 is being used in many of the large research establishments in the US and Europe in nuclear physics, cosmic ray investigations, etc. A list of references is available on request.



Sheets of Plastic Scintillator NE 110 line the inner drift chamber of JADE, a compact magnetic detector specially designed to identify leptons.
(Photograph courtesy DESY, Hamburg, and Dr Robin Marshall)



Annular Plastic Scintillator

For large NE 102A Plastic Scintillator Detectors in NE 8114 Body Monitor, State Hospital, Copenhagen.

NE 104 Plastic Scintillator is used for faster timing experiments. It has a decay time of 1.8ns, a very high light output (68% anthracene) and an attenuation length of 1.2m. It is also suitable for use with BBQ light guides (see NE 104B Plastic Scintillator below).

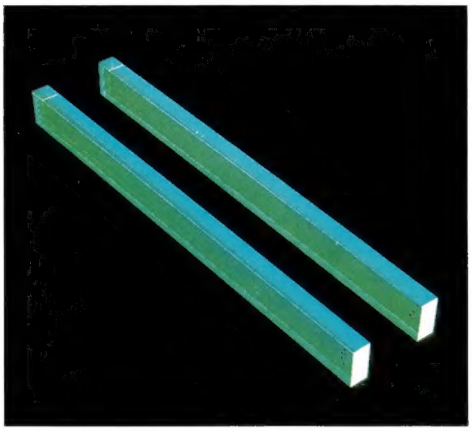
Pilot U Plastic Scintillator is for ultra-fast timing and counting experiments. It has a pulse width of 1.2ns, a decay time of 1.4ns and a high light output (67% anthracene). The alternative fast scintillators **NE 111** and **NE 111A** are being withdrawn from standard production but can still be supplied to special order if required. This is because Pilot U is faster and has a higher light output and much better light transmission than either NE111 or NE111A.

Quenched NE 111 (sometimes called "ZIP") can also be supplied to special order (ref 1). Pulse widths (FWHM) of 0.63ns, 0.45ns and 0.27ns are obtained, but light outputs are low (23%, 14% and 3% anthracene respectively).

NE104B Plastic Scintillators and BBQ Light Guides

Light collection from scintillators using light conversion in fluorescent materials was studied in detail by G Keil (ref 2). The use of wave-shifter bars (rectangular strips or circular rods) greatly simplifies the light collection from large area scintillators, although light collection is less efficient than with conventional clear acrylic light guides which are still recommended when high collection efficiency is essential and space is available for the much larger conventional light guides. Light guides containing the green emitting spectrum shifter BBQ came to be recognised as the most efficient of the "wave-shifter bars" and these were used with tanks of liquid scintillators (NE 235) by B Barish et al (3) and by VK Bharadwaj et al (4), and with plastic scintillator by V Eckardt et al (5). Wave shifter bars are also being used with plastic scintillators at CERN and elsewhere. BBQ wave-shifter bars emit green light

with a wavelength of maximum emission of 495nm. They absorb UV and violet-blue light up to a maximum of about 440nm, but the maximum absorption is at 390nm. They can thus be used with standard plastic scintillators such as NE 102A, NE 110 and NE 114, but much better light collection efficiency is achieved by using a plastic scintillator with a wavelength of maximum emission which matches more closely the absorption maximum of the BBQ. NE 104B plastic scintillator has been developed for this purpose. It has the same wavelength of maximum emission (406nm) as NE 104 but with lower concentrations of scintillation chemicals.
NE 104B has 87% of the light output of NE 104 or about the same light output as NE 110 when measured without a light guide or with conventional light guides. A comparison carried out at CERN showed that the light output of NE 104B, measured through a BBQ light guide, was nearly twice that of NE 102A and four times that of NE 114 measured in the same way (6).
The spectrum shifter BBQ and polyvinyltoluene light guides containing BBQ can be supplied by NE. The usual concentration of BBQ is about 80mg per litre of monomer.


BBQ Light Guides

NE 114 Plastic Scintillator is a low cost scintillator for large installations where a lower light output can be tolerated. Its properties are similar to those of NE 110 except for light output which is about 15% less.

SPECIAL PLASTIC SCINTILLATORS These are for specialised applications as follows, and are available to special order. Details on request.
NE 105 Air Equivalent Plastic Scintillator for radiation dosimetry. **NE 108** Red-emitting Plastic Scintillator for use with silicon photodiodes. **NE 111, NE 111A,** and Quenched Scintillators ("Zip"), see above under Pilot U. **NE 142** Lead Loaded Plastic Scintillator (5% Pb) for detection of low energy gamma rays and x-rays. **NE 160** Plastic Scintillator (cross-linked) for high temperature use.

CHERENKOV DETECTORS

Pilot 425 Plastic Cherenkov Detector

Three outstanding features have been combined in this detector to produce unexcelled efficiencies in Cherenkov detection. Firstly, the more intense Cherenkov light produced at shorter wavelengths is absorbed and re-emitted in the 425mm spectral region. This corresponds to the sensitive region of most standard glass photomultiplier tubes. In addition the light transmission is greatly improved as plastics absorb the shorter wavelength light more strongly. Secondly, the Cherenkov light emitted by Pilot 425 is isotropic rather than directional. This permits more efficient light collection, with the use of internal reflection and the light piping techniques used for plastic scintillators. In the third place, the scintillation effect is reduced to a minimum. The ratio of Cherenkov light to scintillation light, with relativistic electrons, is 10:1.

Standard thicknesses are approx. 1.5mm, 6mm, 12mm and 25mm. The standard sheet size is 1830 x 1220mm (6ft x 4 ft). Other sizes on request. Request bulletin No. 390, and list of references.

Annular Plastic Scintillator

STANDARD SIZES AND SHAPES

Rods for gamma ray and fast neutron detection. Any diameter up to 1 metre (40 inches) is supplied. Lengths of up to 1150 mm (45 inches) are available in some diameters, and up to 600 mm (24 inches) in all diameters.

Wells and Annuli. Any specified geometry can be supplied. Uses include sample counting, anti-coincidence shields, and total absorption gamma ray spectrometers. All surfaces are highly polished, but reflector coating can also be supplied.

Blocks for fast neutron, cosmic ray or gamma ray detection. Rectangular or specially shaped blocks up to 2·5 metres long are supplied to meet individual requirements.

Ingots. Diameters are supplied slightly in excess of nominal diameters to permit machining to size. Machining instructions available on request. **N.B.** Nuclear Enterprises regrets it cannot accept responsibility for cracks or other mechanical defects arising from machining or polishing carried out by customers.

Sheets sizes up to 3·5 metres long for thick sheets (see table below), accelerator and cosmic ray investigations. For alpha and beta particle counting, etc, any desired thickness in the range of thicknesses 0·01 mm to 6 mm or more supplied.

Thin sheets less than 25μm (0·001 inch) are fragile, and at 10μm (0·0004 inch) very fragile and easily torn. For mounted detectors, see NE 810 on page 16.
For NE 102A sheet coated with ZnS(Ag) see under NE 841 Alpha Particle Detector p. 16.

Curved Sheets. Plastic sheets can be formed into curved sheets in order to make annular detectors, etc. For example, NE 110 Plastic Scintillator sheets approx. 800mm long x 10mm thick were bent to form 8 concentric circles varying from 350mm dia. to 1.09m dia. Quotations on any configurations will be supplied on request.

Thickness mm	Maximum Size mm
0·01-0·1	175 x 175
0·125-0·6	200 x 200
0·7-0·9	300 x 300
1	500 x 500
2	1000 x 500
3	1500 x 1000*
5-15	3000 x 750
20-30	2000 x 1000 or 3500 x 500
50-60	1000 x 1000 or 1500 x 600
75-100	1000 x 500

*Preferred maximum size 1000 x 500 mm

Sheet Sizes. The table left may be used as a guide for maximum sizes of particular thicknesses of plastic scintillator sheets (in some cases, larger sizes may be available on special request.) Plastic scintillator sheets can be supplied with machined and polished edges or with roughly cut edges.

Fine Filaments

These are used in the construction of solid scintillation chambers for the recording of nuclear tracks, directional neutron detectors, and internal counting of beta particles in aqueous solution. An assembly of filaments can also be used for image intensifications. Filaments are supplied in 1 metre straight lengths, unless otherwise requested. The greatest care is taken to preserve the original glass-like surfaces, and all direct handling of the filaments is avoided.

Standard diametres of filaments are 0.25, 0.5, 1, 2 and 3mm.

Tubing

The standard size is 1.5mm outside diameter, 0.7mm inside diameter. Uses include the construction of flow cells. (See also NE 801 Flow Cell in Life Sciences Catalogue).

Spheres

For fast neutron counting, dosimetry and beta counting. Diameter 1-10 microns or any required (average) diameter from 0.1 to 1mm. Standard quantities are 10g, 50g and 100g.

DETECTOR ASSEMBLIES INCORPORATING NE 102A

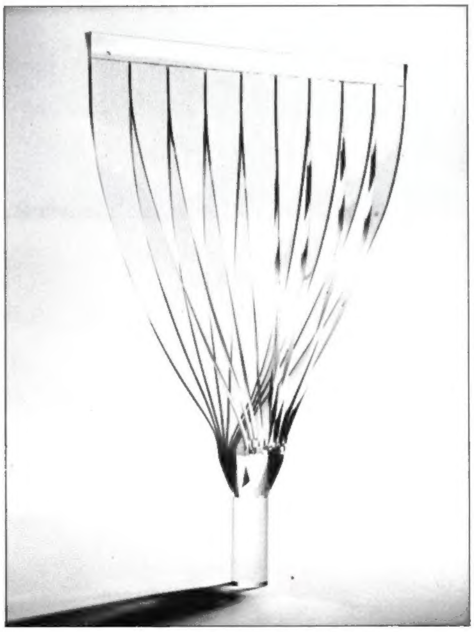
NE 810 Alpha (or Beta) Particle Detector. For full details see page 16 and Bulletin No. 269.

Plastic Scintillator Assemblies for Beta Particle Spectrometry and "Burst Slug" Detectors can be supplied on request.

LIGHT PIPES

With the increased use of large flat sheets the role of light pipes assumes major importance. Adiabatic strip light pipes which show a large improvement in light collection over conventional guides are the most widely used. Each set of light guides has to be designed to suit the particular scintillator geometry and Nuclear Enterprises will be pleased to submit quotations for special requirements.

Other types of light guides of Perspex or polyvinyltoluene include cylinders, truncated cones, "fish tails", etc. BBQ Light Guides can also be supplied (see page 5).



Light Guide

FLOW CELLS

A wide range of flow cells for continuous monitoring of liquids and gases is available. For details see Life Sciences Catalogue. (No 126L).

REFLECTORS FOR SCINTILLATORS NE 560, NE 561, NE 562

NE 560 Titanium Dioxide Reflector is a highly efficient reflector for plastics, crystals, liquid scintillators in glass cells, etc., and is recommended for all scintillators with emission spectra mainly above 400nm. It consists of a sprayed coating, mainly of a special grade of titanium dioxide selected for its high reflectivity. No diffuse reflector such as NE 560 should be used for light collection from large area sheets or other scintillators where there will be numerous reflections before light reaches the photomultiplier. Total internal reflection should then be utilised.

NE 560 is supplied on plastic scintillators as required, and on all encapsulated liquid scintillators unless otherwise instructed. It is also supplied for application by spraying or painting with brush by the customer in the form of a water based emulsion paint. Instructions for applying it are supplied (Bulletin 517). For reflectivity, see graph on page 11. In cans of 1 litre.

NE 561 Titanium Dioxide Reflector contains the same grade of titanium dioxide as NE 560, but its base is a polyurethane and after proper curing, it is recommended in cases where the reflector comes in direct contact with the liquid scintillator. It is then inert to all common liquid scintillators except those containing benzene (NE 230 and and NE 231) and NE 316. See Bulletin 517. For reflectivity, see graph on page 11. In cans of 1 litre with hardener to be added immediately before use.

NE 562 Titanium Dioxide Reflector. For benzene (and other) scintillators, silicate based reflector paint can be supplied. This has excellent adhesion and is inert to nearly all liquid scintillators except the gadolinium and lead loaded scintillators. In cans of 1 litre.

OPTICAL CEMENT NE 581

NE 581 Optical Cement (improved version of NE 580) is a clear colourless epoxy resin which sets at room temperature and has a refractive index close to that of NE 102A and other Nuclear Enterprises plastic scintillators. It is therefore ideal for optically cementing plastic scintillators to light pipes, glass, etc. Supplied in packs of 500ml complete with hardener and instructions for use. See Bulletin 219.

GENERAL DATA ON PLASTIC SCINTILLATORS

Base: polyvinyltoluene; density: 1.032; refractive index (n_D): 1.58; refractive index at wavelength of maximum emission is 1.608 for NE 102A or 1.605 for NE 110; softening point: 70°C; coefficient of linear expansion (below 67°C); approx 7.8×10^{-5}; vapour pressure: negligible; may be used in high vacuum; alpha/beta ratio (NE 102A): 0.072; radiation length: 43cm; light output v. temperature: light output independent of temperature between −60°C and +20°C; light output at +60°C is 95% that at +20°C (ref. 26).

Effects of liquids: The plastic scintillators are soluble in aromatic solvents, acetone, chlorinated solvents etc. They are un-affected by water, dilute acids, alkalis, lower alcohols, pure methyl silicone grease or fluid.

Handling and cleaning: Plastic scintillator sheets are supplied with a protective paper which should not be removed until ready for use. It is advisable to handle all plastic scintillators with cotton or terylene gloves. If the scintillator requires cleaning we recommend an aqueous solution of Perspex No. 3 Polish (available from ICI) and a Selvyt polishing cloth or BPC grade cotton wool. Alternatively Nuclear Enterprises can supply an excellent cleaning/polishing cream. Use of this can often increase the measured light attenuation length. Ethanol or methanol may be used. Machining instructions are available on request.

Gamma-rays: See the nomogram and Gamma-ray Spectra on p 11. For further information on the response of NE 102A to 0.25-2.5 MeV γ-rays, see ref. 7.

Protons: See the following range curve and response curves. The response of NE 102A to protons can be expressed by the following equation (refs 20 and 27)

$$E = 0.95P - 8.0\,(1 - \exp(-0.10P^{0.90}))$$

where P is the recoil proton energy in MeV, and E is the electron energy in MeV that gives the same light output. A graph of the proton response has been published (fig. 7 ref. 27) and a larger version of this can be supplied by Nuclear Enterprises on request. Data for NE 102A on Ionisation Potential (62.6 eV), Mean Z (3.65), Mean A (6.23), stopping power relative to water (0.99) and variation of energy loss with velocity for high energy protons, see ref. 8. The relative light output from NE 102A and other organic scintillators as a function of the initial kinetic energy of the proton is plotted in fig. 25 of ref. 9. For response to 70–100MeV protons, see ref. 25.

High Energy Particles: Rate of energy loss and density effect on NE 110 and NE 102A: ref. 10 and section 6 of ref. 11. Response of NE 102A to muons (ref. 12) cosmic rays (ref. 13); and heavy ions (ref. 13, 14 and 15). See also the NE 110 Reference List available on request.

Neutrons: For detection efficiencies of NE 102A for 1-300 MeV neutrons, see ref. 20, also see refs. 16 and 17 (10-200 MeV) and ref. 18 (10-70 MeV). For low energy neutrons (50-400 keV) see ref. 19.

Low Energy Radiation: (NE 102A). Detection of 1-12 keV electrons (ref. 21) response to 1-10 keV photons (ref. 22) and 1.8-4.5 keV X-rays (ref. 23).

Non-linear and Saturation Effects: With protons, alpha particles, heavy particles, cosmic rays, NE 102A; see ref. 13. With X-rays, NE 102A, NE 111; see ref. 30.

Radiation Damage: (NE 102A). See ref. 24.

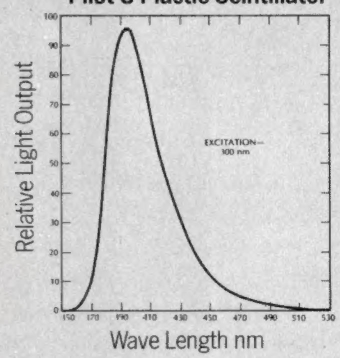
*List of references–see p 21.

TECHNICAL DATA

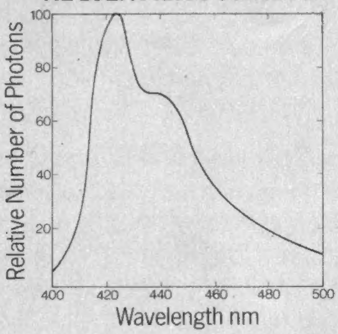
Type	Light Output % Anth.	Pulse Width FWHM ns	Decay Time ns	Rise Time ns	Light Atten. Length cm	Wavelength Max. Emission ns	Ratio H:C Atoms	No. of Electrons per cm³ x 10^{-23}	No. of C atoms per cm³ x 10^{-22}	No. of H atoms per cm³ x 10^{-22}	Principal Applications
NE 102A	65	2.7	2.4	0.9	250	423	1.104	3.39	4.78	5.28	**fast n, protons, electrons etc.**
NE 104	68	2.2	1.8	0.6	120	406	1.100	3.37	4.74	5.21	**fast counting**
NE 104B	59	3	3	1	120	406	1.107	3.37	4.73	5.24	**with BBQ light guides**
NE 110	60	4.2	3.2	1.0	400	434	1.104	3.39	4.78	5.28	**fast n, protons, electrons etc. large area applications**
NE 114	50	5.3	4.0		400	434	1.109	3.37	4.73	5.25	**as for NE 110**
Pilot U	67	1.2	1.4	0.5	100	391	1.100	3.37	4.74	5.21	**ultra fast time**

EMISSION DATA

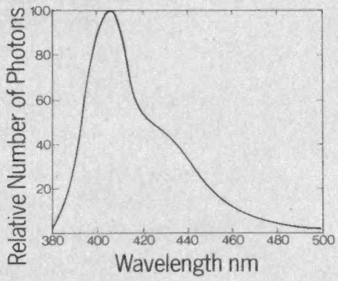
Emission Spectrum of Pilot U Plastic Scintillator



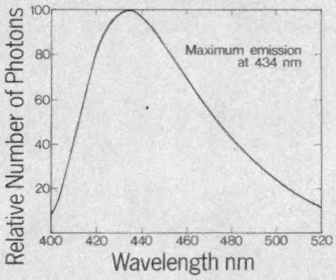
Emission Spectrum of NE 102A Plastic Scintillator



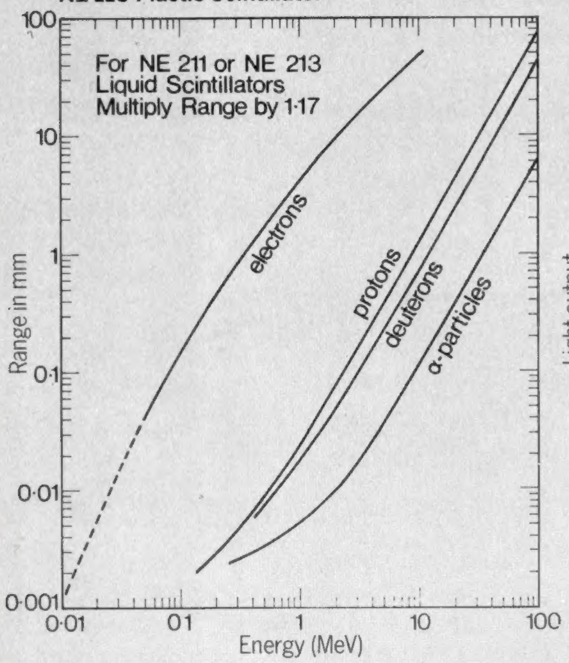
Emission Spectrum of NE 104 and NE 104B Plastic Scintillator



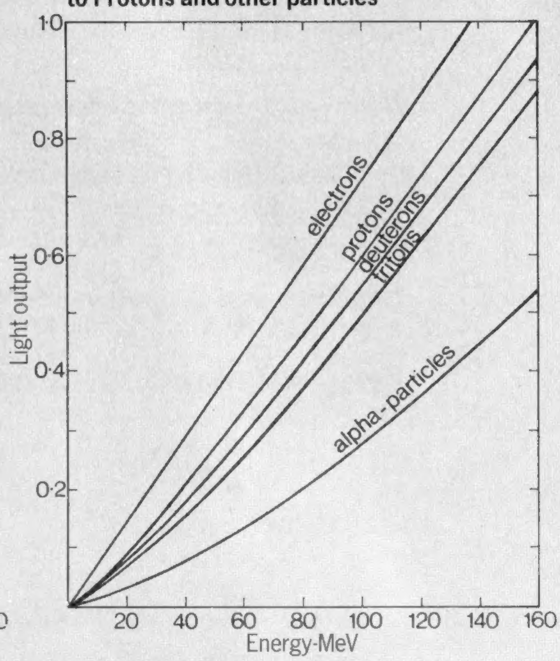
Emission Spectrum of NE 110 and NE 114 Plastic Scintillator



Range of Electrons, Protons, Deuterons and Alpha Particles in NE 102A, NE 104, NE 110, NE 111, and NE 113 Plastic Scintillator

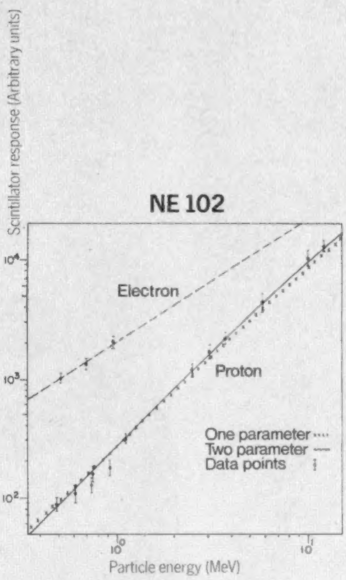


Response of NE 102A Plastic Scintillators to Protons and other particles



Ref. Gooding and Paugh. Nucl. Inst. and Methods 7. 189-192 (1960) and II. 365 (1961).

NE 102



Craun and Smith, Nucl. Instr. & Meth., 80, 239-244 (1970)

Gamma-Detection Efficiency of Organic Phosphors

Nucleonics, 15, (10), 86, (1957)
By K.I. ROULSTON and S.I.H. NAQVI
Department of Physics, University of Manitoba, Winnipeg, Canada

This nomogram and the accompanying curves make possible a rapid determination of the detection efficiency of an organic phosphor. For detection a certain minimum energy must be transferred to a Compton electron. The cross section can be calculated by integrating the differential Compton cross section from the corresponding minimum photon scattering angle to 180 deg (Fig. 1).

One starts with the minimum acceptable energy transfer (discriminator-bias setting). From Fig. 1 one then finds the cross section for detectable energy transfer, σ. To determine the corresponding absorption co-efficient μ (=$\rho\sigma$) we use the three nomogram scales at left. The nomogram then determines the efficiency ($1-e^{-\mu x}$) from μ and the thickness x.

The method assumes equality of total linear absorption coefficient and detection absorption coefficient. This is generally justified by crystal geometries in which a photon that is scattered by an event not leading to detection cannot escape from the crystal without traversing the remainder of the path lengths.

With 25-keV bias we observe efficiences that correspond to our curve above 2 keV below 200 keV, the cross section is larger than calculated apparently due to multiple collisions.

Example: Discriminator bias is at 25 keV, and we are detecting 200-keV photons in a 10-cm-thick plastic phosphor. From the curves we find a detection cross section of 0·27 barns. A representative phosphor has ρ=0·34 x 10^{24} electrons/cm^3. With this assumption we find a detection efficiency of 60%.

Note: Plastic Scintillators NE 102A, NE 104, NE 104B, NE 110, NE 114 and Pilot U: ρ=0·338 x 10^{24} electrons/cm^3.
Liquid Scintillator NE 213: ρ=0·293 electrons/cm^3.

Detection cross section vs incident photon energy

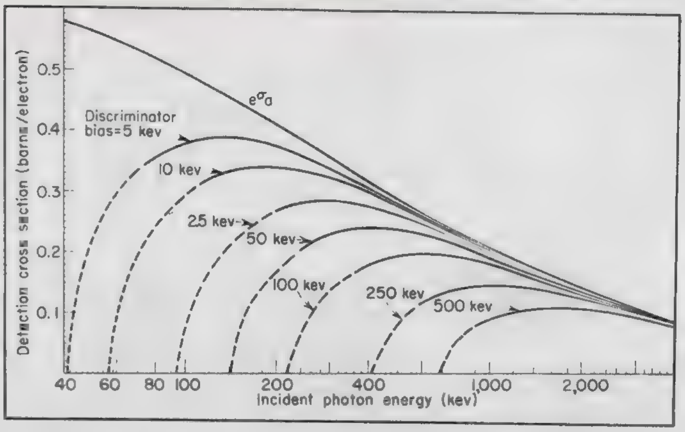
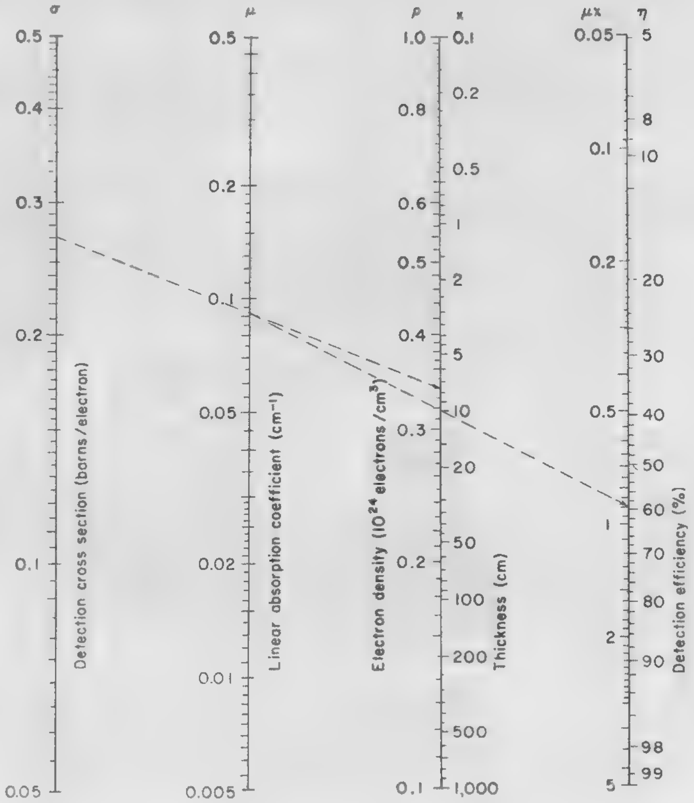
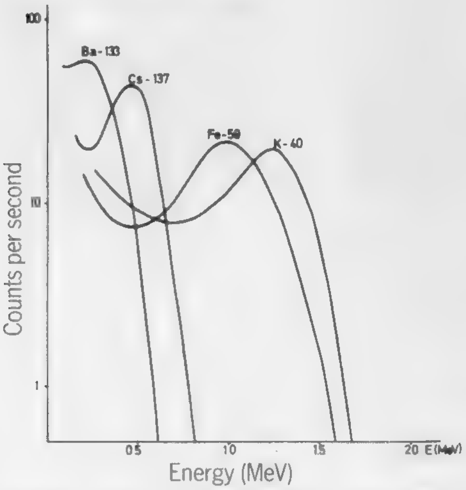


Fig 1.

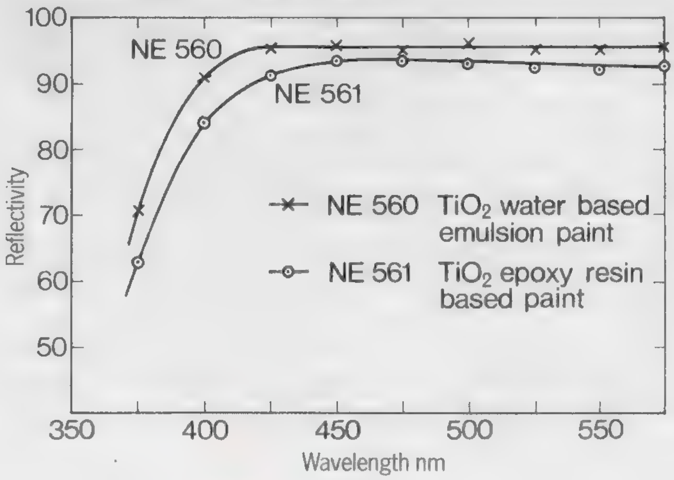


Gamma-ray Spectra



Gamma-ray spectra obtained with NE 102A plastic scintillator blocks from "A Whole Body Monitoring Laboratory". H. Sköldborn, B. Arvidsson and M. Andersson, Acta Radiologica, Supplement 313, pp. 233-241 (1972). The resolutions (HWHM) obtained were 15% for ^{40}K and 23% for ^{136}Cs.

Reflectivity of Reflector Paints



LIQUID SCINTILLATORS

The range includes standard liquid scintillators for external detection of radiation, loaded liquids for neutron and gamma detection, and for pulse shape discrimination applications. Liquid scintillators are available in bulk form or encapsulated in cells or tanks with reflector. All liquid scintillators should be stored in clean, dry sealed containers under an atmosphere of inert gas. (Liquids are shipped under nitrogen). Materials suitable for construction of containers, etc., in contact with liquid scintillators are glass, tin-plated steel, chrome steel, stainless steel, aluminium, indium and PTFE. The stability of each liquid in presence of other materials should be determined before a large amount of liquid is committed. Some liquid scintillators may be used in acrylic (Perspex etc.) containers (see following table). For optimum performance, liquids should be deoxygenated prior to use by displacement with nitrogen (oxygen free) or inert gas.

The wavelength of maximum emission of our standard liquid scintillators is 425nm.

Note: Liquids for internal sample counting–see Life Sciences Brochure No. 126L.

Scintillator	Relative Light Output (Anthracene 100)	Decay Constant ns	Ratio H/C Atoms	Gamma Ray Detection	Fast Neutron Detection	Thermal Neutron Detection	Pulse Shape Discrimination	Large Volume Tanks	High Flash Point	No Attack On Acrylics*	Loading Elements	Comments
NE 213	78	3·2	1·212	x	x		x					Excellent P.S.D. properties
NE 224	80	2·6	1·330	x	x			x	x	x		High light output and transmission
NE 226	20	3·3	0	x	x		x		x		(F)	Negligible H content
NE 230	60	3·0	0·984†		x		x				(^{2}H)	Deuterated benzene base
NE 232	40	4	1·96†		x						(^{2}H)	Deuterated cyclohexane base
NE 235	40	4	2·0	x	x			x	x	x		Mineral oil base
NE 311	65	3·8	1·701			x	x				B	Neutron detection: natural-boron
NE 311A	65	3·7	1·701			x	x				^{10}B	Neutron detection: ^{10}B
NE 313	62	4·0	1·220		x	x		x			Gd	Neutron spectrometry
NE 316	35	4·0	1·411	x							Sn	Gamma and X-ray detection
NE 323	60	3·8	1·377		x	x		x	x		Gd	Neutron Spectrometry

* Perspex, Lucite or Plexiglas. † D/C Ratio

UNLOADED LIQUID SCINTILLATORS

NE 213 Liquid Scintillator

☐ For pulse shape discrimination applications (neutron detection)

This scintillator consists of specially purified xylene, naphthalene, activators and spectrum shifter. NE 213 shows excellent pulse shape discrimination properties, particularly for neutron counting in presence of gamma radiation. NE 213 is almost universally adopted as the standard scintillator for neutron spectrometry. Dissolved oxygen must be removed, after which NE 213 exhibits pulse shape discrimination properties comparable with those of stilbene crystals. It can be supplied ready for immediate use in an encapsulated alumimum or glass cell. For its response to protons and neutrons (1MeV-300MeV), see ref. 20.
NE 213 is deoxygenated and shipped under purified nitrogen, but should be thoroughly deoxygenated again, by displacement with nitrogen or inert gas, immediately prior to use with pulse shape discrimination techniques.
Data/Reference List on request (Bulletin 404 (1979).
Light output: 78% anthracene. Decay constant: 3.2ns. Flash point: 24°C. Neutron detection efficiency: ref. 20.

NE 224 Liquid Scintillator (pseudo-cumene)

☐ Highest light output ☐ High flash point ☐ Inexpensive

This liquid scintillator is based on specially purified pseudo-cumene (1, 2, 4 trimethylbenzene), and has a light output which is slightly higher than the best xylene or toluene scintillator. It has a high flash point, excellent light transmission and low cost, and is therefore ideal for use in large liquid scintillator tanks.

Light output: 80% anthracene. Flash point: 48°C. Decay constant: 2.7ns. Further details and references are given in Bulletin 270.

LIQUID SCINTILLATORS

NE 226 "Hydrogen-free" Liquid Scintillator

☐ For gamma ray and neutron detection

NE 226 is based on hexafluorobenzene and as it is almost free from hydrogen, it is useful for gamma ray detection in a fast neutron flux using pulse shape discrimination techniques and can also be used as a neutron detector when moderation of neutrons is required to be avoided.

Further details and references are given in Bulletin 275.

NE 230 and NE 232 Deuterated Liquid Scintillators

These scintillators based on Benzene-d6 and Cyclohexane-d12 respectively are used for neutron studies. Details and references are given in Bulletin 338.

NE 235 Mineral Oil Scintillator

This scintillator is recommended for use in large tanks when low cost is important and very high light output is not essential. Its light output (40% anthracene) is, however, appreciably greater than that of other mineral oil scintillators.
NE 235 may be used with BBQ light guides (see ref. 3).
Sixty-eight cubic metres of NE 235 have been used at the Fermi National Accelerator Laboratory. Ref. A. Benvenuti et al, "A liquid scintillator total absorption hadron calorimeter for the study of neutron interactions", Nucl. Instr. & Methods 125. 447-456 (1975).
NE 235 has a very high flash point, excellent light transmission, and may be used in metal, glass or acrylic (Perspex, Plexiglas or Lucite) containers. Technical data on NE 235 are given in Bulletin 338.

LOADED LIQUID SCINTILLATORS

NE 311A Boron Loaded Liquid Scintillator

NE 311A contains 5% boron which is enriched in ^{10}B to 90%. It has excellent pulse shape discrimination properties.[28] This scintillator is supplied in bulk form or in the standard types of sealed cells. Data sheet supplied on request.
Also available at lower cost with natural boron (NE 311).

NE 313 and NE 323 Gadolinium Loaded Liquid Scintillator

The thermal neutron cross-section of gadolinium is the highest of any element, and NE 313 is recommended for neutron spectrometry. The standard concentration of gadolinium is 0.5% by weight but other concentrations can be supplied on request. Scintillator efficiency and neutron cross section measurements have been made using a special scintillator tank manufactured by Nuclear Enterprises Ltd., and filled with 240 litres NE 313. See figure on p 15 and ref. 29. Data sheet with references on request (NE 313 and NE 323).
NE 323 is a high flash point (38°C) version of the xylene based NE 313 (flash point 24°C). The light output is 60% anthracene (NE 313, 62%), and the decay time is 4ns. A data sheet with references can be supplied on request.

NE 316 Tin Loaded Liquid Scintillator

NE 316 Liquid Scintillator provides a detector of much higher gamma sensitivity than can be obtained with unloaded liquid or plastic scintillators and has a higher light output than lead loaded scintillators.
Tin content: 10% w/w. Light output: 35% anthracene. Decay constant: 4.0ns.

Other Loaded Liquid Scintillators

These are available to special order on request.

Liquid Scintillator Store

ENCAPSULATED LIQUID SCINTILLATORS

All Nuclear Enterprises liquid scintillators are available encapsulated in glass cells of appropriate composition. The liquids are carefully deoxygenated for stability and for optimum light output and each cell is provided with a reservoir of oxygen-free nitrogen. The cells are supplied with a thin coating of an efficient diffuse white reflector unless requested otherwise. The following types of cell are available. When ordering, please state which is required, giving internal dimensions.

Type BA1 The "bubble free" alumimum cell has a white internal reflector, glass window and no visible expansion chamber. The latter consists of a concealed PTFE tube round the circumference. (See illustration).

Standard sizes of BAI cells are given in the following table. Other sizes can be supplied on request.

Internal diameter, mm	50	50	50	125	125	125	125
Internal length, mm	50	125	150	50	75	100	125

BA1 Cells

Type BA2 The above cell with 2 viewing windows.

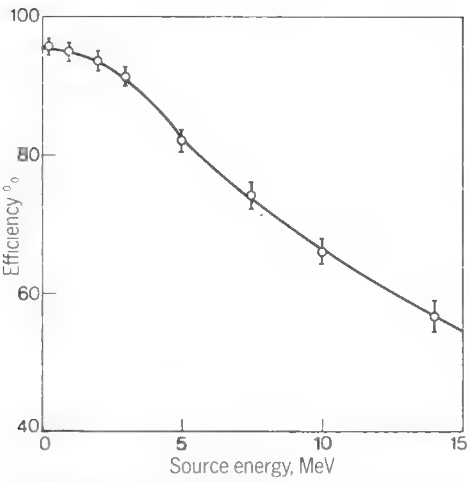
Type VH1 Pyrex glass cell with side arm designed so that the cell can be used for both vertical and horizontal viewing with a single photomultiplier. Standard sizes are 38mm diameter (1.5 in) x 38mm, 50mm dia. (2 in) x 50mm, 75mm dia. (3 in) x 75mm and 125mm dia. (5in) x 125mm (internal dimensions). Other sizes on request.

Type VH2 As type VH1 both end-faces ground and polished for viewing with two photomultipliers.

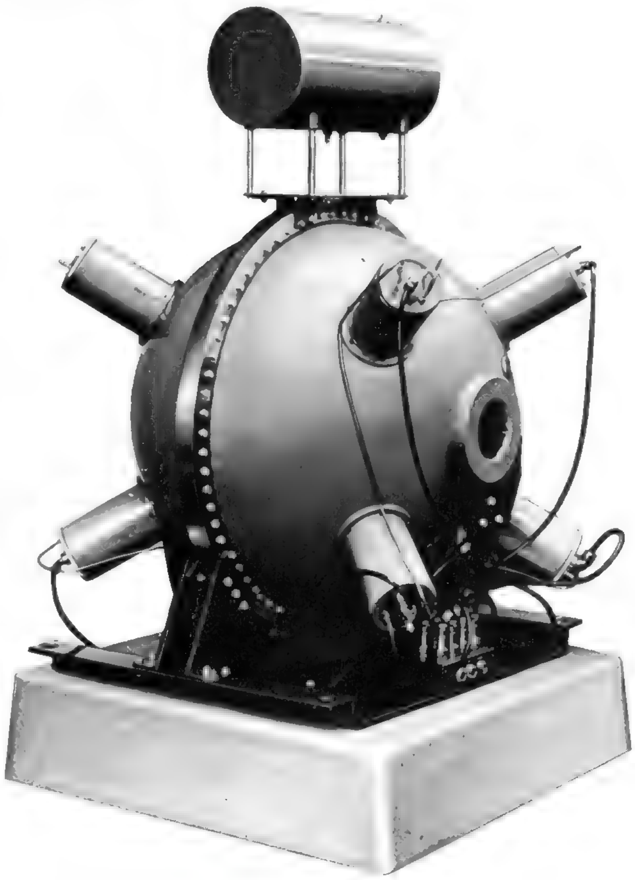
Special non-standard cell to meet particular requirements can be supplied.

LIQUID SCINTILLATOR TANKS

Nuclear Enterprises can supply liquid scintillation tanks for anti-coincidence counting, gamma ray spectrometry, fast neutron spectrometry, etc. Special attention is paid to light collection factors, leak testing, scintillator stability and oxygen removal facilities.



Scintillator efficiency as a function of neutron energy. NE 313 spherical tank, 760mm (30in) diameter. J.B. Parker, et al, ref. 29.



ALPHA AND BETA PARTICLE DETECTORS

NE 810 IMPROVED ALPHA (OR BETA) PARTICLE DETECTOR

NE 810 Detectors are manufactured by optically cementing thin NE 102A plastic scintillator sheet to a Perspex light guide disc. Because of its low sensitivity to gamma radiation, the NE 810 Detector is ideally suited to low level monitoring problems with alpha particles, heavy ions, fission fragments etc. It gives a resolution of 7% for 5.1 MeV alpha particles and has a decay time of 2.4 ns.
Any circular, square or rectangular shape up to 130mm or 5in linear dimension can be supplied. Manufacture of larger sizes will be considered. See Bulletin 269.
Standard Diameters: 25mm (1in), 38mm (1½in), 50mm (2in), 75mm (3in), 100mm (4in), 125mm (5in), 150mm (6in).

NE 810/DM-5 Beta Detector

NE 810 DETECTOR ASSEMBLIES

The above NE 810 detectors can also be supplied as complete detector assemblies incorporating entrance window, NE 810, photomultiplier, magnetic shield and dynode chain (also preamplifier if required). The standard sizes of photomultipliers are 2in (50mm), DM1-2, 3in (75mm), DM1-3 and 5in (125mm), DM1-5.

NE 840A AND NE 840C ALPHA PARTICLE DETECTORS

☐ Low sensitivity to gamma radiation. ☐ Large light output

The NE 840A Alpha Particle Detector is based on ZnS(Ag) phosphor. The unit consists of a thin layer of ZnS(Ag) bonded to a Perspex disc of 6.4mm thickness. The phosphor layer is covered by double aluminised plastic film of density 0.96mg/cm^2, permitting the detector to be used in full illumination. It is mounted in a metal ring securing a protective wire mesh.
The NE 840C Alpha Particle Detector is unmounted and consists of a Perspex disc to which is bonded a layer of ZnS(Ag).
Standard Diameters: 25mm (1in), 38mm (1½in), 50mm (2in), 75mm (3in), and 125mm (5in).
These detectors (and NE 841 below) can be supplied as complete assemblies as described above under NE 810 Detector Assemblies.

NE 841 ALPHA-BETA PARTICLE DETECTOR

NE 102A plastic scintillator discs or sheet can be supplied with a thin coating of ZnS(Ag) for simultaneous counting of alpha and beta particles. Pulse height selection is used to discriminate between the particles. Please specify thickness of scintillator required. If not specified, a thickness of 0.5mm will be supplied.
Standard Diameters: As for NE 840A (above).

NEUTRON DETECTORS

Table of Comparison

Scintillator	Type	Decay Time ns	Fast n	Thermal n	Gamma ray response	P.S.D.	Loading elements	Comments
NE 422	disc	200		x	very small	x	^{6}Li	contains ZnS (Ag)
NE 426	rectangular	250		x	very small		^{6}Li	n radiography
NE 451	cylinder	200	x		very small	x	H	
NE 905	glass	18 and 60	x	x	small for thin detector		^{6}Li	
NE 908	glass	75	x	x	small for thin detector		^{6}Li	
NE 912	glass	75	x	x	small for thin detector		^{6}Li	low background
NE 102 A	plastic	2·4	x		yes		H	
NE 213	liquid	3·7	x		yes	x	H	in cells
NE 226	liquid	3·3	x		yes	x	F	in cells
NE 311 A	liquid	3·8		x	yes	x	^{10}B	in cells
NE 313	liquid	4·0	x	x	yes		Gd	in large tanks
NE 323	liquid	3·8	x	x	yes		Gd	in large tanks
Stilbene	crystal	4·5	x		yes	x	H	small detectors
^{6}LiI(Eu)	crystal	1200	x	x	yes		^{6}Li	high resolution

NE 422 Neutron Detector

NE 451 Neutron Detector

SLOW NEUTRON DETECTORS

NE 422 Thermal Neutron Detector

- ☐ 55% detection efficiency for thermal neutrons
- ☐ Excellent discrimination against gamma background
- ☐ Grooved for improved light collection
- ☐ Compact design for easy mounting

An improved neutron detector is available for efficient detection of thermal neutrons in the presence of gamma radiation. NE 422 employs a lithium compound, whose Li content is enriched to 95% ^{6}Li dispersed in a ZnS(Ag) matrix. The design of this detector represents an improved version of that reported by Stedman (ref. 32). The NE 422 detector replaces the earlier NE 421 neutron detector.

Efficient measurement of thermal neutron fluxes may be performed in the presence of gamma radiation as high as 10^7 gamma rays per neutron. Technical data are included in Bulletin No. 250.

Standard Diameters: 25 mm, 38 mm, 50 mm, 75 mm, 125 mm. Other sizes or geometries on special request.

NEUTRON RADIOGRAPHY

NE 426 Detector for Neutron Radiography

The new NE 426 detector is based on ZnS(Ag) and ^{6}Li, and is an improved version of the older NE 425 and NE 421 detectors. The composition, thickness and method of manufacture have been optimised for image resolution and sensitivity in collaboration with A. R. Spowart (Ref. 34). The scintillation efficiency is approximately 27 eV/photon (Ref. 33).

NE 426 is a flat and usually rectangular detector which is non-hygroscopic, and is mounted (unless otherwise requested) on an aluminium plate 1mm thick. The detector surface is placed in close contact with a suitable photographic film such as Ilford Industrial Type B. The image resolution obtainable is better than 0·1 mm.

Representative Sizes: 82·5 x 108 mm (3·25 x 4·25 in.), 120 x 165 mm (4·75 x 6·50 in.) and 180 x 240 mm (7·1 x 9·45 in.). Other sizes readily available on request.

NE 432 Neutron Radiography Camera

This camera incorporates the above NE 426 detector 120 x 165 mm* (4·75 x 6·50 in.) and a spring-loaded mounting for the photographic film (Ilford Industrial type B flat film) in a light-tight box. The film is normally adequately exposed after 2 minutes with a flux of 10^4 thermal neutrons/cm^2/s, or a few seconds irradiation from a 100 kW reactor. *Alternative size 180 x 240 mm (7·1 x 9·45 in.).

Note 1: An alternative scintillator for neutron radiography is an NE 905 glass scintillator (see p. 18) 1 mm thick, coated on one side with black paint (Ref. 48). This scintillator gives a somewhat clearer picture, but requires up to 80 times the exposure necessary with NE 426.

FAST NEUTRON DETECTORS

NE 451 Fast Neutron Detector

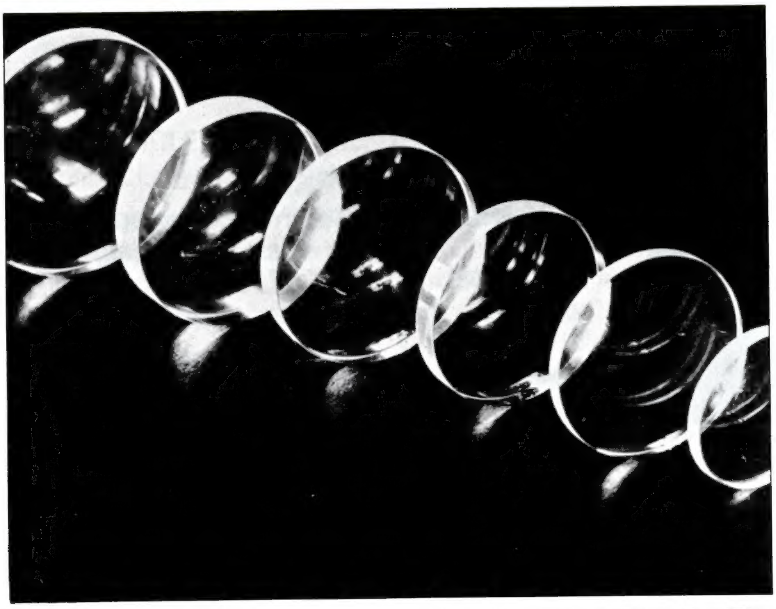
- ☐ Fast neutron detection efficiencies of up to 5%

The NE 451 Fast Neutron Detector is a modification of the Emmerich[44] and Skarsvag scintillation detectors. It employs a clear hydrogenous plastic as moderator and uses ZnS(Ag) phosphor. Light collection is improved by furnishing cylindrical light guides, and an integrally mounted reflector.

The NE 451 detector shows maximum emission at 450 nm and decay constant (principal component) 2×10^{-7} seconds. The thickness is 16 mm unless otherwise specified.

Standard Diameters: 25 mm, 38 mm, 50 mm, 75mm, 125 mm. Other diametres on special request.

GLASS SCINTILLATORS



Glass Scintillators NE 901–NE 913

Uses

Cerium activated lithium silicate glass scintillators have the following uses:

1. Neutron detection.

2. Detection of beta particles including ^{3}H (ref. 35), gamma rays, etc., when the environment (e.g. corrosive liquids or vapours) or high temperature make other scintillators unsuitable. NE 901 is recommended here.

3. Neutron radiography: NE 905 glass scintillators 1 mm thick coated with black absorber on one side have given an optical resolution of less than 0·001 in. (0·025 mm). See also page 17 and ref. 34.

Types

The following types are available (percentages are by weight).

NE 901 2·4% natural Li (also available enriched (NE 902) or depleted (NE 903) in ^{6}Li).

NE 905 6·6% lithium enriched in ^{6}Li to 95% (also available with natural Li (NE 904).).

NE 908 7·5% lithium enriched in ^{6}Li to 95% (also available with natural Li (NE 907) or depleted in ^{6}Li (NE 909).).

NE 912 7·7% lithium enriched in ^{6}Li to 95% (low background).

NE 913 8·3% lithium depleted in ^{6}Li, 99·99% ^{7}Li (low background).

Properties

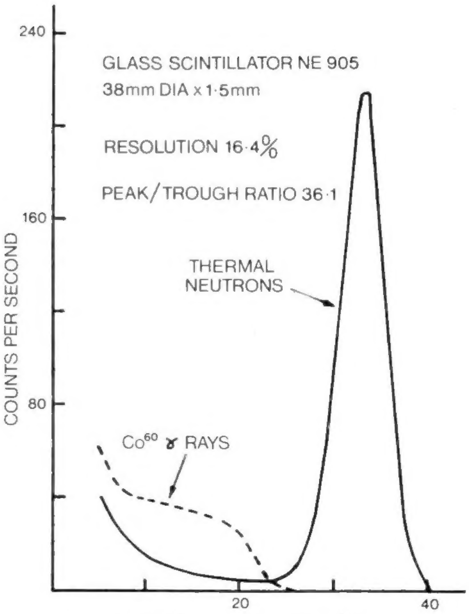
Chemical: Scintillating glasses are particularly noteworthy for their chemical resistance to all organic and inorganic reagents except hydrofluoric acid. The high melting point and excellent physical characteristics of these glasses together with their excellent chemical resistance permit their use under extreme environmental conditions where measurements with other scintillating materials would not be possible.

Temperature: The effects of temperature on light output of all the glass scintillators over the range −196° to +127° C have been reported by A.R. Spowart (ref. 36).

The following table summarises the properties of those scintillators which are enriched in ^{6}Li.
The properties of NE 901 and NE 903 are similar to those of NE 902; NE 904 and NE 906 are similar to NE 905; NE 907 is similar to NE 908 and NE 913 is similar to NE 912 except in respect of their response to neutrons.

	NE 901	NE 905	NE 908	NE 912
Density (approx.)	2·64	2·5	2·42	2·4
Refractive Index	1·58	1·55	1·566	1·55
Coefficient of linear expansion /°C.	$7{\cdot}0 \times 10^{-6}$	$9{\cdot}23 \times 10^{-6}$		
Wavelength of maximum emission	395 nm	395 nm	395 nm	397 nm
Light Output relative to anthracene	22–34%*	20–30%*	20%	25%
Decay times†, neutron excitation, ns	–	18, 57 & 98	18, 62 & 93	18, 55 & 90
Decay times†, alpha excitation, ns	20, 48 & 88	16, 49 & 78	15, 45 & 56	18, 44 & 60
Decay times†, beta excitation, ns	19, 57 & 103	20, 58 & 105	17, 51 & 96	19, 52 & 93
Alpha/beta ratio	0·23			
Resolution on the thermal neutron "peak" obtained with moderated ^{210}Po/Be neutrons	13–22% (NE 902)	15–28%	20–30%	15–26%
Peak/trough ratio of above "peak" (range)	15:1 to 40:1 (NE 902)	10:1 to 40:1	10:1 to 20:1	10:1 to 20:1
Melting point	c. 1200°C.	c. 1200°C.	c. 1200°C.	c. 1200°C.
Background alpha activity per 100g glass	100–200 d.p.m.	100–200 d.p.m.	100–200 d.p.m.	less than 20 d.p.m.

* According to thickness, increasing with decreasing thickness down to approximately 2 mm.
† Fast component, slow component and 90–10% respectively (ref. 37).



Typical response curves with NE 905 glass scintillators

Background

The two glass scintillators, NE 912 and NE 913, with extremely low backgrounds are available for neutron spectrometry, time-of-flight work and other applications. Their background activity is less than 20 disintegrations per minute per 100 grams of glass, compared with 100 to 200 d/min. per 100 g of the other glass scintillators. This very low background is achieved by special additional purifaction of the three constituents, Li_2O, SiO_2 and Ce_2O_3. Surface contamination is avoided using special polishing materials which are free from any activity. NE 912 containing ^{6}Li is for neutron detection and NE 913 containing ^{7}Li for detection of electrons, γ-rays etc.

Gamma-ray Response

When used as neutron detectors, the glass scintillators NE 905, NE 908 and NE 912 afford excellent pulse height discrimination against gamma radiation, particularly in the case of thin glasses.
The data on gamma sensitivities given in the following table are from ref. 38.

Scintillators and thickness	Gamma photons to give same light output as 1 neutron			Measured gamma attenuation coefficients* (M)		
	^{226}Ra	^{137}Cs	^{60}Co	^{226}Ra	^{137}Cs	^{60}Co
NE 905 1mm	850	240	100	3·06	3·16	1·63
NE 905 1·5mm	550	160	74	8·16	7.89	2·17
NE 905 3mm	390	100	50	27·50	23·16	5·43
NE 908 6·2mm	310	81	57	37·80	33·69	25.00

*These values will be under-estimates due to the detection of degraded Compton photons. The actual error will be worse for the 1mm thick glass and least for the thick samples.

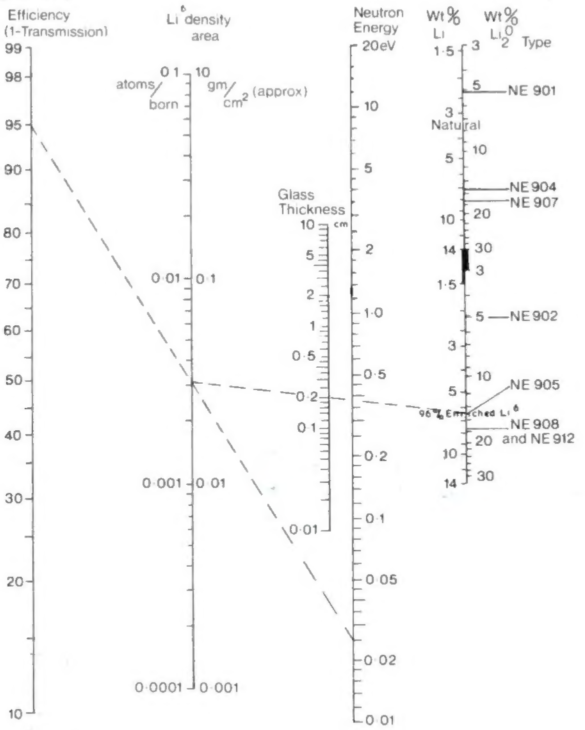
As the glass scintillators depleted in ^{6}Li, NE 903 and NE 913, are insensitive to neutrons, they may be used in conjunction with NE 902, NE 905 and NE 912 for measuring any residual background due to high intensity gamma radiation, etc.

GLASS SCINTILLATORS

Neutron Efficiencies

Detection efficiencies of glass scintillators for slow neutrons (0·01–20eV) may be obtained from the nomogram which has been adapted from ref. 39. The example indicated by the broken line indicates that the efficiency of a 2 mm thick NE 905 glass scintillator for thermal neutrons (0·025eV) is 95%.
The measured absolute scintillation efficiency for thermal neutrons of NE 905 (1 mm thick) without reflector is 700eV/photon and the number of emitted photons for captured thermal neutron is 6700. (Reference 33). This paper also quotes figures for 3 mm thick NE 905 (510eV and 9200) and 6 mm thick NE 908 (600eV and 7900), and states that coating the scintillator with alpha-alumina reflector should decrease the value of the absolute scintillation efficiency by about a factor of three.

Detection efficiencies for slow neutrons. A nomograph relating the lithium content, neutron energy, thickness and efficiency of lithium glass scintillators. The broken line indicates the method of relating the various quantities. (Ref. 39).



For the response of NE 905, NE 908, etc. to other neutron energies, refer to the appropriate papers in the following table.

Neutron Energy	Type	Thickness	Ref
0·01–1eV	All types	0·1–100 mm	39
Thermal	NE 905	1 mm	33
10eV–100keV	NE 905	3·2 mm	40
10eV–1MeV	NE 905	12·7 mm	41
*100eV–1MeV	NE 905 (GS20)	25·4 mm	42
*10eV–10MeV	NE 908	12·7 mm	43
1–600keV	NE 908 (KG2) NE 905 (GS20)	9·5 mm	44
100–450keV	NE 905	9·5 mm	45
1–6MeV	NE 905	25 mm	45

*Copies of Efficiency v. Neutron Energy Graphs obtained with and without polythene available on request.

Responses to α and β particles, neutrons

Ranges, ionisation densities and response of all the glass scintillators to α and β particles and neutrons have been reported by A.R. Spowart (ref. 47).

Time-of-Flight Detector

A time resolution of 3·4 ns (fwhm) has been measured for NE 905 used as a neutron time-of-flight detector (Ref. 48, and see also ref. 49).

Forms Available

Cylinders: The glasses are clear and colourless and are normally supplied in cylindrical sections with both faces ground flat and one face polished. On request both faces may be polished and either an alpha alumina or evaporated aluminium reflector can be furnished. The former is preferred and recommended as being of higher efficiency.
Annuli, wells and truncated cones can be supplied on request.

Standard Diameters mm	Maximum Thickness mm	Standard Thicknesses mm	Standard Thicknesses mm
10	50	0·5	6·4
25·4	50	1	10
38	25	2	12·7
44	25	3	20
51	25	4	25.4
63·5	25	5	50
76	25		
89	25		
102	19		
111	12·7		
114	12·7		
127	12·7		
153	6·4		
178	6·4		
190	3		

Square or Rectangular Sheets: up to 150 x 150mm can be supplied. When used for neutron radiography the usual thickness of sheets is 1mm, and if required they can be coated on one side with black paint to sharpen the image.
Filaments: Any of the glass scintillators can be supplied in filaments up to 200mm long. Any diameter between 0·2 and 1·5mm can be supplied. Tolerance on diameter for hand-pulled filaments is $\pm$ 25%.
Powder: For use in special flow cells etc. for counting ^{14}C and other beta particle emitters. NE 901 is suitable for this, but other types can also be supplied. It can be supplied ground to any required maximum size in the range 0·25 to 3·0mm with no minimum size specified (minimum quantity 10g). It can also be supplied graded between two sizes such as the following:

0·1 and 1·0mm	0·2 and 0·4mm
0·25 and 1·0mm	0·25 and 0·3mm
	0·5 and 3·0mm

Minimum quantity: 5g.

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Lists of References (available on request):

Fast Neutron Spectrometry using NE scintillators.
Cerenkov Counting (High Energy and Low Energy).
NE Whole Body Monitors.
Measurement of Potassium using Whole Body Monitors.
IN-VIVO Neutron Activation Analysis.
NE 110 Plastic Scintillator.
CsI (T1) Scintillation Detectors.
Anticoincidence and Anti-Compton Systems for Gamma-Ray Spectrometry.
Plutonium Detection (Pu-in-Wound, Pu IN-VIVO, Pu in Waste).
Faeces Counters.
Well-type Scintillation Counters (1. Crystal; 2. Plastic).
Ion Detection by Scintillation Counters, etc.
Whole Body Monitors with Computers.
Spectrum Stabilisers.
Very Low Energy Gamma and Soft X-ray Detection.
Response of NE Plastic, etc., Scintillators to Protons, Deuterons, etc.
Use of NE Scintillators, etc., for Neutron Radiography.
Use of NE 313 and NE 323 Gadolinium Loaded Scintillators.
Low Energy Gamma and X-ray Scintillation Detection.
CaF_2 (Eu) Scintillation Detectors.
Use of Dual Scintillator "Phoswich" Detectors for Pu and U determination "IN-VIVO".
Uranium-in-lung measurements using Whole Body Monitors.
Radon and its daughters measured in the Human Body using WBM's., etc.
Fast Timing Techniques using Fast Photomultipliers.
NE Neutron Detectors with Pulse Shape Discrimination.
NE Neutron Detectors for Time-of-flight spectroscopy.
Wavelength Shifters.
Measurement of soft tissue by Photon Absorption.
Loaded plastic scintillators.
Whole Body Monitors for Animals.
Photodiodes and Scintillators.
2π and 4π Counters for (Radioactive Source Assay).
Glass Scintillators.
Glass Scintillators for slow neutrons.
Glass Scintillators for fast neutrons.
Alpha Scintillation Detectors.
Measurement of Potassium, etc., in Fertilizer, etc.
Radiation Damage to Plastic Scintillators.

Associated Equipment

The Nuclear Enterprises range includes a wide selection of radiation counters and head units. Full details of the equipment listed below are available on request:

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CAMAC modules and systems.
Scaler Ratemeter SR5.
Scaler Timer ST6.
Portable Scaler Ratemeter PSR6.
Scintillation Counter Assembly 6006.
Lead Castles 710A and 7106.
Wide range of Probes.
Health Physics Instruments for Environmental and Personnel Radiation Monitoring, including CM6 Contamination Monitor and HM6 Hand Monitor.
Whole Body Radiation Monitors